Rock Types and Model Inputs

Shale and sandstone are the two major rock types modeled at HGSS. The Cambrian-aged Mt. Simon Sandstone is quartz-rich and offers pore space between quartz grains. The Eau Claire Formation is predominantly shale, clay-rich, and comprised of small particles that are tightly packed and impermeable.

Table 1 list the layers in the model and their rock type assignments. Thought the Pre-Cambrian basement has been included in the model, its flow properties were estimated to be similar to those of shale due to comparable pore architecture and tightness.

Table 1. Relative permeability set allocations for the storage model in CMG-GEM.

Layer Start	Layer End	Formation/Unit	Rock Type
1	9	Eau Claire	Shale
10	19	Upper Mt. Simon (E)	Sandstone
20	27	Upper Mt. Simon (D)	Sandstone
28	37	Middle Mt. Simon (C)	Sandstone
38	47	Lower Mt. Simon (B)	Sandstone
48	67	Lower Mt. Simon (A) – Upper Member	Sandstone
68	77	Lower Mt. Simon (A) – Lower Member	Sandstone
78	80	Argenta	Sandstone
81	83	Weathered Basement	Basement/granite
84	87	Precambrian Basement	Basement/granite

The flow behavior of these rock types was described using two separate relative permeability sets as described below. There were no available core analyses for this specific project location which resulted in the use of analogous data from nearby wells and literature. Two separate sets of relative permeability curves were used, one for the porous sand zones and another for confining shale layer. The two sets of relative permeability curves were:
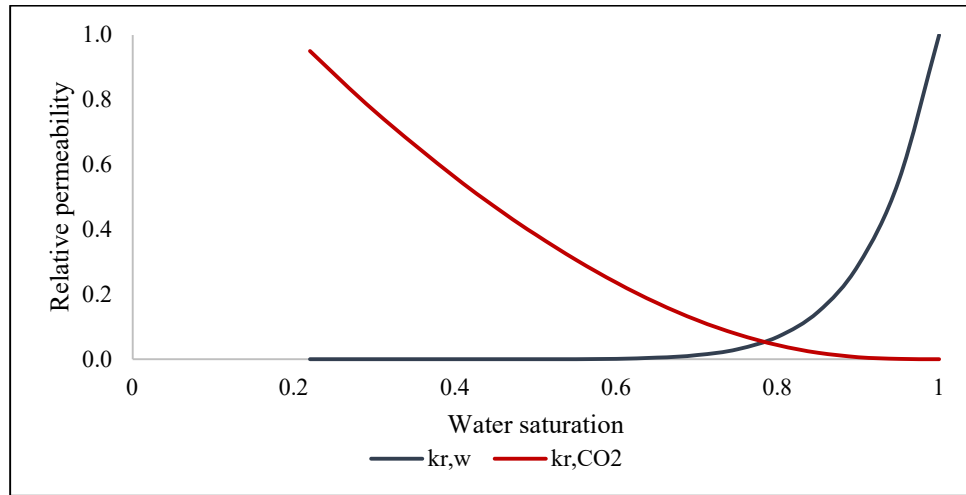
- **Set Number 1:** CO_2-water drainage curve for Mt. Simon sandstone published by Krevor *et al.* (2011)[1] based on samples from a well in Macon County, IL; samples were taken at 5,400 ft. depth and subjected to coreflooding experiments with brine and CO_2. Experimental data was further fit using Brooks-Corey correlations to extrapolate to

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[1] Krevor, S.C.M., Pini, R., Zuo, L., and Benson, S.M., 2012. Relative permeability and trapping of CO2 and water in sandstone rocks at reservoir conditions. *Water Resources Research* Vol. 48, doi: 10.1029/2011WR010859

saturation end points. **Figure 1** shows the drainage curve used for this study. Raw data is presented in **Table 2**.

- **Set Number 2**: CO_2-water drainage curve for a shale confining layer with nominal pore sizes distribution comparable to that of the Eau Claire shale published by Bennion and Bachu (2007)[2]. Data for the Calmar shale was used as an analog since the median pore size for this formation was 0.006 µm, which is comparable to Eau Claire nominal pore distribution of 0.002-0.01 µm. **Figure 2** shows the CO_2-brine drainage curve for the tighter (< 1 mD) units in the model that includes the Eau Claire shale. **Table 4** lists the relative permeability curves assigned to model zones. Raw data is presented in **Table 3**.

Figure 1. CO_2-brine drainage curve for Mt. Simon sandstone (Krevor *et al*., 2011)

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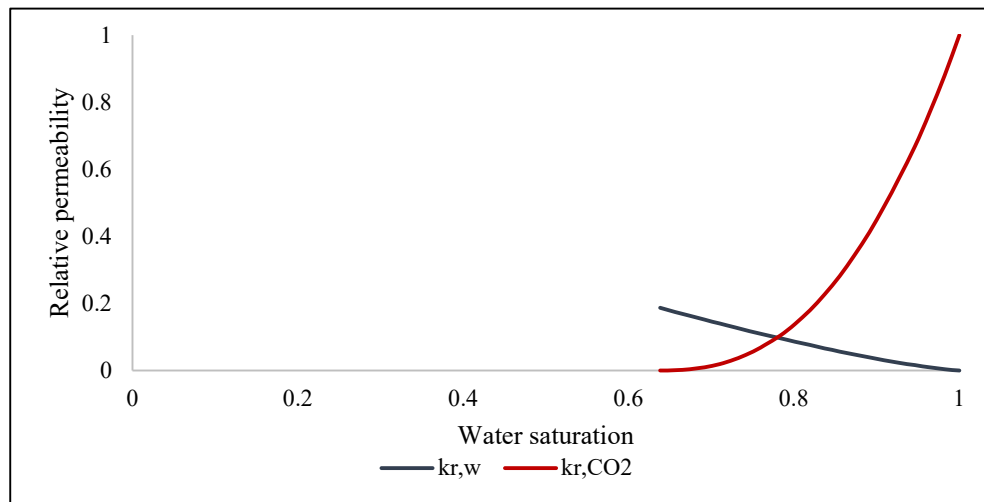
[2] Bennion, D.B., and Bachu, S., 2007. Permeability and Relative Permeability Measurements at Reservoir Conditions for CO_2-Water Systems in Ultra Low Permeability Confining Caprocks. SPE Paper # 106995 presented at the SPE Europec/EAGE Annual Conference and

Exhibition, London, United Kingdom, 11–14 June.

Figure 2. CO₂-brine drainage curve for Eau Claire shale (adapted from Bennion and Bachu, 2007)

Table 2. Relative permeability data for Set Number 1.

Water Saturation (S_w)	k_{r,w}	k_{r,CO2}
0.22	0.00	0.95
0.30	0.00	0.77
0.40	0.00	0.56
0.46	0.00	0.45
0.50	0.00	0.38
0.55	0.00	0.31
0.60	0.00	0.24
0.65	0.00	0.17
0.70	0.01	0.12
0.75	0.03	0.08
0.80	0.07	0.04
0.85	0.15	0.02
0.90	0.29	0.01
0.95	0.55	0.00
1.00	1.00	0.00

Table 3. Relative permeability data for Set Number 2.

Water Saturation (S_w)	k_{r,w}	k_{r,CO2}
1	0	1
0.982	0.0039	0.8803
0.964	0.0095	0.7697
0.946	0.016	0.6679
0.927	0.0232	0.5747
0.909	0.031	0.4897
0.891	0.0393	0.4128
0.873	0.048	0.3437
0.855	0.057	0.282
0.837	0.0664	0.2276
0.819	0.0762	0.18
0.801	0.0862	0.139
0.783	0.0965	0.1042
0.764	0.107	0.0752

Water Saturation (S_w)	$k_{r,w}$	$k_{r,CO2}$
0.746	0.1178	0.0518
0.728	0.1288	0.0334
0.71	0.1401	0.0197
0.692	0.1515	0.0101
0.674	0.1632	0.0041
0.656	0.1751	0.001
0.638	0.1871	0

Table 4. Relative permeability set allocations for the storage model in CMG-GEM.

Layer Start	Layer End	Formation/Unit	Rock Type	Relative Permeability Set Number
1	9	Eau Claire	Shale	2
10	19	Upper Mt. Simon (E)	Sandstone	1
20	27	Upper Mt. Simon (D)	Sandstone	1
28	37	Middle Mt. Simon (C)	Sandstone	1
38	47	Lower Mt. Simon (B)	Sandstone	1
48	67	Lower Mt. Simon (A) – Upper Member	Sandstone	1
68	77	Lower Mt. Simon (A) – Lower Member	Sandstone	1
78	80	Argenta	Sandstone	1
81	83	Weathered Basement	Basement	2
84	87	Precambrian Basement	Basement	2